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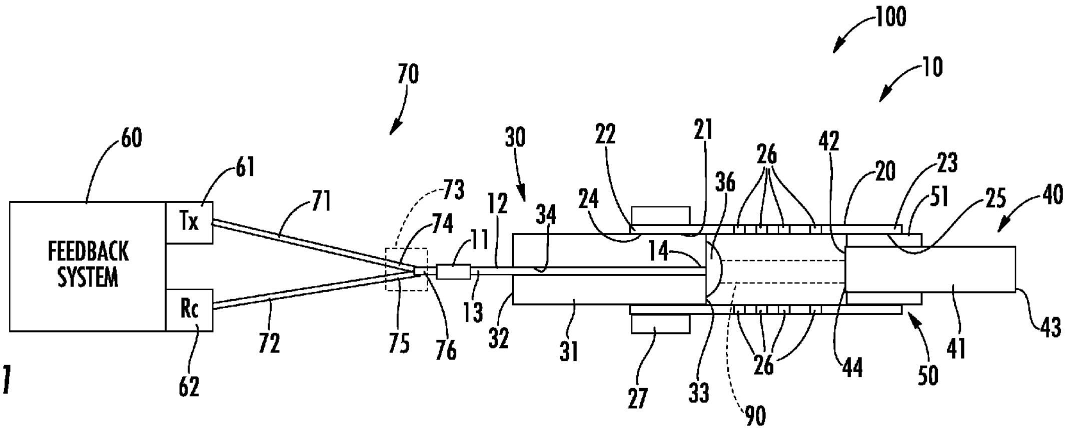

FIG. 1

(57) **Abstract:** A gas analysis module includes a housing having a passage with a source section and a reflector section. A reflector module is disposed on the housing at the reflector section and the reflector module includes a reflector. A lens module is disposed on the housing at the source section and is spaced from the reflector module. The lens module includes a waveguide and an aligned collimating lens defining a light path optically aligned with the reflector. A mounting structure permits relative movement of the reflector module and the lens module and a fixing element is operative to secure the reflector module relative to the lens module.

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MODULE FOR GAS ANALYSIS SYSTEM

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 62/357,666, filed July 1, 2016, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to modules for use in the analysis of gasses and, more particularly, to a gas analysis module that includes a reflector for reflecting light used with a gas analysis system.

BACKGROUND ART

[0003] Measurement of the amount of gasses such as CO_2 within an exhaled breath may be used to monitor patient health in a non-invasive manner. For example, relatively high or low levels of CO_2 or rapid changes in the CO_2 levels may be indicative of different health concerns and may aid the diagnosis of medical conditions. It has been determined that CO_2 within an exhaled breath will affect the ability of certain wavelengths of light to pass through the breath. Capnography systems measure the amount of CO_2 within an exhaled breath by measuring the manner in which the light at a desired wavelength passing through the breath is affected by the CO_2.

[0004] Devices for performing such CO_2 measurement may utilize certain wavelengths of light such as infrared light. The use of these wavelengths typically requires a significant amount of precision and thus devices or modules for use with these systems may be difficult to manufacture and relatively expensive. A relatively simple, robust module for use with gas analysis systems would be desirable.

[0005] The foregoing background discussion is intended solely to aid the reader. It is not intended to limit the innovations described herein, nor to limit or expand the prior art discussed. Thus, the foregoing discussion should not be taken to indicate that any particular element of a prior system is unsuitable for use with the innovations described herein, nor is it intended to indicate that any element is essential in implementing the innovations described herein. The implementations and application of the innovations described herein are defined by the appended claims.

SUMMARY

[0006] In one aspect, a gas analysis module includes a housing having a passage with a source section and a reflector section. A reflector module is disposed on the housing at the reflector section and the reflector module includes a reflector. A lens module is disposed on the housing at the source section and is spaced from the reflector module. The lens module includes a waveguide and an aligned collimating lens defining a light path optically aligned with the reflector. A mounting structure is between the reflector module and the housing to permit movement of the reflector module relative to the lens module and a fixing element is between the housing and the reflector module to secure the reflector module relative to the lens module.

[0007] In another aspect, a method of manufacturing a gas analysis module includes providing a housing having a passage with a source section and a reflector section, positioning a reflector module including a reflector on the housing at the reflector section, positioning a lens module on the housing at the source section and spaced from the reflector module with the lens module including a waveguide and an aligned collimating lens, and providing a light source through the waveguide and the collimating lens to define a light path. The method further includes reflecting light from the light path off the reflector and through the collimating lens to a measuring system, measuring an amount of reflected light received at the measuring unit, pivoting the reflector module relative to the lens module to adjust an angular alignment position of the reflector relative to the light path, repeating the steps of measuring and pivoting to adjust the angular alignment position of the reflector relative to the lens module through a plurality of angular alignment positions until an amount of reflected light meets a predetermined threshold, and securing the reflector module relative to the lens module at an angular position corresponding to an angular position at which the amount of reflected light meets the predetermined threshold.

[0008] In still another aspect, a gas analysis module includes a housing having a passage with a source section and a reflector section. A reflector module is disposed on the housing at the reflector section and the reflector module includes a reflector. A lens module is disposed on the housing at the source section and is spaced from the reflector module. The lens module includes a waveguide and an aligned collimating lens defining a light path optically aligned with the reflector. A mounting structure permits relative movement of the reflector module and the lens module and a fixing element is operative to secure the reflector module relative to the lens module.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Fig. 1 is a schematic illustration of a gas analysis system utilizing a module incorporating concepts of the present disclosure;

[0010] Fig. 2 is a schematic illustration similar to Fig. 1 but further including a reflector adjustment system;

[0011] Fig. 3 is a schematic illustration of the module of Fig. 2 but with a cover secured thereto;

[0012] Fig. 4 is a schematic illustration of a gas analysis system utilizing a second embodiment of a module incorporating concepts of the present disclosure;

[0013] Fig. 5 is an end view of the module of Fig. 4;

[0014] Fig. 6 is a schematic illustration similar to Fig. 5 but further including a reflector adjustment system;

[0015] Fig. 7 is a schematic illustration of the module of Fig. 6 but with a cover secured thereto;

[0016] Fig. 8 is a schematic illustration of a third embodiment of a module incorporating concepts of the present disclosure;

[0017] Fig. 9 is an end view of the lens module of the module of Fig. 8;

[0018] Fig. 10 is a schematic illustration of the module of Fig. 8 but with a cover secured thereto;

[0019] Fig. 11 is a schematic illustration of a gas analysis system utilizing a fourth embodiment of a module incorporating concepts of the present disclosure; and

[0020] Fig. 12 is a schematic illustration of a module and a reflector adjustment tool.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Fig. 1 depicts a gas analysis system such as capnography system 100 that includes a feedback system 60, a coupling system 70, and a gas analysis module 10. The capnography system 100 may operate by transmitting infrared light through optical components and measuring how the light is affected by CO_2 along a portion of the transmission path. The feedback system 60 includes a transmitter 61 for generating and transmitting light, such as infrared light, through the coupling system 70 to the gas analysis module 10. The receiver 62 receives light from the gas analysis module 10 through the coupling system 70. The feedback system 60 is operative to analyze an amount or percentage of reflected light that is returned from the gas analysis module 10 through the coupling system 70.

[0022] The coupling system 70 includes a first or transmitter waveguide 71 such as a single mode optical fiber optically connected to the transmitter 61. A second or receiver waveguide 72 such as a single mode optical fiber is optically connected to the receiver 62. The transmitter waveguide 71 and the receiver waveguide 72 may be optically connected to a splitter 73. The splitter 73 includes a pair of waveguides 74, 75 at one end and a single waveguide 76 at an opposite end. The splitter 73 is configured so that all or a percentage of the light transmitted through the first waveguide 74 connected to transmitter waveguide 71 will pass through the splitter and exit through the single waveguide 76. Light that enters the single waveguide 76, such as from gas analysis module 10, will be split or divided as it passes through the splitter 73. In doing so, a first percentage of the light will pass through the first waveguide 74 and into the transmitter waveguide 71. A second percentage of the light will pass through the second waveguide 75 and into the receiver waveguide 72. Depending upon the characteristics of the splitter 73, the light entering the single waveguide 76 may be split evenly between the first waveguide 74 and the second waveguide 75.

[0023] Gas analysis module 10 includes a housing 20, a lens module 30, and a reflector module 40. In one embodiment, the housing 20 may be generally tubular or cylindrical with a central cylindrical passage or bore 21. The housing 20 may include a first or lens end 22 and a second or reflector end 23 spaced from the lens end. A lens aperture 24 may form a portion of bore 21 at or adjacent the lens end 22 and an adjustment aperture 25 may form a portion of the bore at or adjacent the reflector end 23. The housing 20 may include a plurality of openings 26 to permit a gas such as exhaled air to pass laterally through the passage 21. In one embodiment, housing 20 may be formed of a moldable resin or polymer. Housing 20 may be formed of any other desired material, in any desired manner, and have any desired shape. In some instances, it may be desirable for the housing 20 to be relatively rigid to maintain the desired optical alignment as described in further detail below.

[0024] Lens module 30 includes an optical waveguide holder or ferrule 31. In one embodiment, ferrule 31 may include a connection end 32 and an opposite lens end 33 with a bore 34 extending between the connection end and the lens end. The bore 34 may be configured to receive a single mode optical fiber 12 therein. The lens module 30 may further include a collimating lens 36 disposed at the lens end 33 of the ferrule 31. In one embodiment, the ferrule 31 may be formed of a moldable resin or polymer. Additives may be included with the moldable material used to form the ferrule 31 to increase the dimensional stability of the ferrule, if desired. Lens 36 may be formed of an optical grade resin or polymer capable of being molded. In one embodiment, lens 36 may be mounted to the lens end 33 of ferrule 31 during the manufacturing process. In another embodiment, the lens 36 may be integrally molded as part of the ferrule 31.

[0025] Reflector module 40 includes a body section 41 with a reflector end 42 and an opposite tool engaging member or tool end 43. A reflector 44, such as a mirror, may be disposed at the reflector end 42. In one embodiment, the body section 41 may be formed of any desired material and the reflector 44 secured to the body section 41. In another embodiment, the body section 41 may be formed of any desired material and the reflector 44 formed as part of the body section. The reflector 44 may be formed of any desired material and in any desired manner. In one example, the reflector 44 may be formed by an additive process such as by plating a surface of the reflector. In another example, the reflector 44 may be formed by a subtractive process such as finishing and/or polishing. In another embodiment, the body section 41 may be formed of a reflective material such as aluminum and the reflector 44 may formed by finishing and/or polishing the reflector end 42 so that it has a desired surface or finish.

[0026] The tool end 43 is configured to be engaged by a reflector module adjustment tool 80 (Fig. 2). In one embodiment, the tool end 43 may be cylindrical so as to be engageable by a bore in the adapter engagement end 81 of adjustment tool 80. In another embodiment, the tool end 43 may include a bore and the adapter engagement end 81 of adjustment tool 80 includes a complementary configuration.

[0027] To assemble gas analysis module 10, an optical connector 11 may be terminated to a first end 13 of a waveguide such as single mode optical fiber 12. A second end 14 of the single mode optical fiber 12 is positioned within bore 34 of ferrule 31 of lens module 30. The ends 13, 14 of the optical fiber 12 may be laser cleaved, polished, or finished in any other desired manner.

[0028] The lens module 30 is inserted into the lens end 22 of bore 21 of housing 20 through lens aperture 24 and secured or fixed in any desired manner. In one example, a cylindrical clamp or crimp sleeve 27 may be secured around the lens end 22 to secure the lens module 30 at the lens end of housing 20. In another example, the lens module 30 may be secured within the bore 21 with an adhesive. In still another example, the lens module 30 may include deformable ribs 237 (Fig. 8) that create an interference fit with the bore 21 upon inserting the lens module into the bore.

[0029] The reflector module 40 is inserted into the reflector end 23 of bore 21 of housing 20 through adjustment aperture 25. A mounting structure 50 is provided between the reflector end 23 and reflector module 40 to permit the reflector module to be moved relative to the housing 20 during a reflector alignment process. Such movement is primarily pivoting of the reflector module 40, but the reflector module may also undergo some translational movement depending upon the configuration of the mounting structure 50. As depicted in Fig. 1, the mounting structure 50 may be a malleable, deformable, or crushable cylindrical sleeve 51 between the bore 21 of housing 20 and the body section 41 of reflector module 40. The sleeve 51 may initially be secured within the bore 21 or secured to the outer surface of the body section 41 prior to insertion of the reflector module 40 into the bore. The mounting structure 50 may operate to temporarily secure the reflector module 40 at the reflector end 23 of bore 21. In one embodiment, sleeve 51 may be formed of a relatively soft metal. In another embodiment, sleeve 51 may be formed of a polymer, resin, foam, or any other desired material.

[0030] Once the lens module 30 and the reflector module 40 have been mounted on the housing 20, the reflector module is aligned relative to the lens module. To do so, the feedback system 60 and coupling system 70 are connected to gas analysis module 10 by connecting the single waveguide 76 to the optical connector 11. In some instances, the waveguide 76 may be terminated to a second optical connector (not shown) which is then terminated to optical connector 11.

[0031] To align the reflector module 40, an optical signal of a predetermined strength is transmitted by the transmitter 61 through transmitter waveguide 71 and into the splitter 73. A percentage of the light transmitted by the transmitter 61 exits the transmitter 73 through waveguide 76 and enters the optical fiber 12. The light transmitted through the optical fiber 12 passes through collimating lens 36 and exits as a column of light, depicted in phantom at 90. The column of light 90 reflects off the reflector 44 and returns to the collimating lens 36.

[0032] The collimating lens 36 re-focuses the column of light 90 that is returned from the reflector 44. To the extent that the reflector 44 is aligned with the collimating lens 36, all of the light from the column of light 90 will be focused on and transmitted back through the core of the optical fiber 12. However, in a single mode optical fiber, the core typically has a diameter of 8-10 μm. Accordingly, even a small amount of misalignment between the collimating lens 36 and the reflector 44 will substantially reduce the amount of light received at the core of the optical fiber 12.

[0033] In order to reduce the amount of misalignment between the collimating lens 36 and the reflector 44 and thus maximize the amount of reflected back from the reflector, a system may be connected to the tool end 43 of reflector module 40 and feedback system 60 to manipulate the reflector module and adjust the alignment of the reflector 44 relative to the collimating lens 36. More specifically, a reflector adjustment system, generally indicated at 65 in Fig. 2, is operatively connected to the tool end 43 of reflector module 40 and receives information from feedback system 60. The reflector adjustment system 65 may operate to move the tool end 43 of reflector module 40 while the feedback system 60 measures the amount of light reflected back through the collimating lens 36 and is received at the receiver 62. While the sleeve 51 may be operative to temporarily retain the reflector module 40 relative to the housing 20, it may be deformed (such as at 52) as the tool end 43 of reflector module 40 is moved to optimize or maximize the amount of light that is reflected from reflector 44 to the collimating lens 36 as depicted in Fig. 2. It should be noted that the angular orientation of reflector module 40 depicted in Figs. 2-3 is exaggerated for clarity.

[0034] In one embodiment, the reflector adjustment system 65 may move the tool end 43 of reflector module 40 through a series of possible positions and use a feedback and analysis methodology such that the tool end is moved towards positions at which the amount of reflected light received at receiver 62 increases and away from positions at which the amount of reflected light decreases. After a sufficient number of possible positions had been analyzed, the reflector adjustment system 65 may select or identify the position of the tool end 43 at which the amount or percentage of reflected light is maximized.

[0035] In another embodiment, the reflector adjustment system 65 may move the tool end 43 of reflector module 40 through a large number (e.g., all or essentially all) of possible positions and record the amount of reflected light for each position. The reflector adjustment system 65 may then select or identify the position of the tool end 43 at which the amount or percentage of reflected light is maximized.

[0036] In still another embodiment, a plurality of possible positions of the tool end 43 of reflector module 40 may be identified and the reflector adjustment system 65 may begin moving the tool end to each of the possible positions and the amount or percentage of reflected light determined. Upon the amount or percentage of reflected light exceeding a predetermined threshold, the reflector adjustment system 65 may terminate the process and utilize the position at which the amount or percentage of reflected light exceeded the threshold as the desired position of the tool end 43 of reflector module 40. Other manners of determining the desired position of the tool end 43 are contemplated.

[0037] Once the desired position of the tool end 43 of reflector module 40 has been selected or identified, a fixing element 45 may be used to secure the reflector module to the housing 20 in the desired orientation relative to the housing. The fixing element 45 may be an adhesive or any other desired material or structure. In one example, the adhesive may be a relatively instantly hardening bonding agent such as diallyl phthalate. In another example, the adhesive may be a UV curable epoxy which requires a secondary curing step. Other types of adhesives are contemplated.

[0038] After the reflector module 40 has been secured or fixed in its desired orientation, a cover or cap 15 may be secured to housing 20 as depicted in Fig. 3. The cover 15 may be configured to enclose the adjustment aperture 25 at the reflector end 23 of housing 20 and the tool end 43 of reflector module 40. An adhesive may be located within the cover 15 to further secure tool end 43 in place. The cover 15 may thus protect the reflector module 40 and reduce the likelihood that it will be moved from its desired aligned position.

[0039] Referring to Figs. 4-7, an alternate embodiment of a gas analysis module 110 is depicted. Like reference numbers may be used to identify like components. Gas analysis module 110 may be substantially identical to gas analysis module 10 of Figs. 1-3 but module 110 utilizes an alternate embodiment of a mounting structure 150 provided between the reflector end 23 of housing 120 and reflector module 40 to permit the reflector module to be moved relative to the housing during the reflector alignment process. More specifically, the housing 120 may include a plurality of spaced apart, inwardly extending engagement projections 151 disposed around an inner surface or circumference 28 of bore 21. The bore 21 thus has a diameter greater than the diameter of the outer surface 46 of body section 41 of reflector module 40 and the projections 151 accommodate the difference in diameters. The three points of contact between the projections 151 and the outer surface 46 of body section 41 permit primarily pivoting movement of the reflector module 40 relative to the housing 20 as depicted in Fig. 6.

[0040] The orientation of reflector module 40 may be adjusted relative to housing 20 and/or lens module 30 as described above to optimize or maximize the amount of light reflected within the gas analysis module 110. Once the reflector module 40 is set to or positioned at the desired orientation, the reflector module may be secured with fixing element 45. Cover 15 may be secured to housing 20 to enclose the adjustment aperture 25 at the reflector end 23 of housing 120 and the tool end 43 of reflector module 40.

[0041] Referring to Figs. 8-10, another alternate embodiment of a gas analysis module 210 is depicted. Like reference numbers may be used to identify like components. Gas analysis module 210 may be substantially identical to gas analysis module 10 of Figs. 1-3 but module 210 utilizes deformable ribs 237 along the outer surface 238 of the lens module 230 that create an interference fit with the bore 221 of housing 220 upon inserting the lens module into the bore. The interference fit between the lens module 230 and the bore 221 may be used to secure the lens module to the housing 220. In some instances, the deformable ribs 237 may be used in combination with an adhesive to secure the lens module 230 within the bore 221.

[0042] In addition, reflector module 240 of gas analysis module 210 may be formed with a generally spherical body section 241 and a reflector 244 disposed at the reflector end 242 and an elongated tool or post 245 extending from an opposite end 243. The body section 241 and the elongated post 245 may be integrally formed such as by molding from a resin or polymer. In one embodiment, reflector support 246 may also be integrally formed with body section 241 and the end face 247 thereof plated to create a reflective surface that operates as a reflector 244 or a separate reflective element may be mounted to the end face. In another embodiment, reflector support 246 may be formed of a reflective material and the end face 247 finished and/or polished and the reflector support mounted or secured to the body section 241 opposite the elongated post 245. The spherical body section 241 may interact with the reflector end 23 of housing 220 and function as a mounting structure 250 to permit the reflector module 240 to be moved relative to the housing during the reflector alignment process. In other words, the spherical surface of the body section 241 will permit primarily pivoting movement of the reflector module 240 relative to the housing 220 as depicted in Fig. 10.

[0043] The orientation of reflector module 240 may be adjusted relative to housing 20 and/or lens module 230 as described above to optimize or maximize the amount of light reflected within the gas analysis module 210. Once the reflector module 240 is set to or positioned at the desired orientation, the reflector module may be secured with fixing element 45. Cover 15 may be secured to housing 220 to enclose the adjustment aperture 225 at the reflector end 23 of housing 220 and the post 245 of reflector module 240.

[0044] Referring to Fig. 11, still another alternate embodiment of a gas analysis module 310 is depicted with an alternate embodiment of the coupling system 370. Like reference numbers may be used to identify like components. Coupling system 370 may be similar to coupling system 70 of Figs. 1-2 but the coupling system 370 eliminates splitter 73. In doing so, transmitter waveguide 71 may be a single mode optical fiber that is optically connected to transmitter 61 and extends to optical connector 311. Receiver waveguide 72 may be a single mode optical fiber that is optically connected to receiver 62 and extends to optical connector 311. As such, the coupling system 370 includes two distinct waveguides. In one embodiment, the transmitter waveguide 71 and the receiver waveguide 72 may be optically connected to optical connector 311. In another embodiment, the transmitter waveguide 71 and the receiver waveguide 72 may be terminated to a second optical connector (not shown) that is subsequently terminated to the optical connector 311.

[0045] Gas analysis module 310 may be substantially identical to gas analysis module 110 of Figs. 4-7 but lens module 330 of gas analysis module 310 includes a pair of adjacent bores 334, 338 extending between the connection end 332 and the lens end 337. The bores 334, 338 may be closely aligned with the centerline of the lens module 330 and the collimating lens 36 centered along the centerline. A first or transmit waveguide such as single mode optical fiber 312 may extend from optical connector 311 through bore 334 and be terminated adjacent collimating lens 36. A second or receiver waveguide such as single mode optical fiber 317 may extend from optical connector 311 through bore 338 and is terminated adjacent collimating lens 36. The structure of gas analysis module 310 may be otherwise identical to that of gas analysis module 110.

[0046] The orientation of reflector module 40 may be adjusted relative to housing 20 and/or lens module 330 generally as described above to optimize or maximize the amount of light reflected within the gas analysis module 310. However, when aligning the reflector module 40, rather than orienting the reflector 44 to direct the collimated beam of light to the collimating lens 36 so that the light is focused along the centerline of the reflector module and thus the core of the optical fiber 312, the reflector 44 is oriented so that the collimating lens 36 focuses the collimated beam of light on the core of the receiver waveguide or single mode optical fiber 317.

[0047] In operation (and while adjusting the orientation of the reflector module 340), light passes from transmitter 61 through transmitter waveguide 71, through connector 311 and into transmit waveguide or optical fiber 312. Light passes from optical fiber 312 and exits collimating lens 36 as a collimated beam of light 90. It should be noted that due to the offset configuration of the bore 334 through which optical fiber 312 passes, the collimated beam 90 may not exit the collimating lens along the centerline of the lens. The collimated beam 90 is reflected off reflector 344 back to collimating lens 36. The orientation of reflector module 340 may be altered or modified until the collimating lens 36 focuses the collimated beam 90 on the core of the receiver waveguide or optical fiber 317 so that a sufficient or maximum amount of light is transmitted back through the receiver waveguide 72 to the receiver 62.

[0048] Once the reflector module 340 is set to or positioned at the desired orientation, the reflector module may be secured with fixing element 45. A cover may be secured to housing 20 to enclose the adjustment aperture 25 at the reflector end 23 of housing 120 and the tool end 43 of reflector module 40.

[0049] Fig. 12 depicts a diagrammatic illustration of a reflector module adjustment tool 80. The adjustment tool 80 includes an adapter engagement end 81 configured to engage the post 245 of reflector module 240 of gas analysis module 210. As may be understood from Fig. 12, the relatively long length of the adjustment tool 80 permits or simplifies relatively fine adjustments of the orientation of the reflector 244. More specifically, the spherical body section 241 functions as a pivot point or fulcrum 248 for the combination of the adjustment tool 80 and the reflector module 240. Since the movement of the adjustment tool 80 adjusts or controls not only the position of the reflector 244 but also the position or location at which the column of light 90 reflected by the reflector contacts the collimating lens 36. As a result, the amount of movement of the end 91 of the column of light 90 at the collimating lens 36 is a ratio of the distance 83 between the fulcrum 248 and the collimating lens 36 and the distance 84 between the fulcrum and the distal end 82 of adjustment tool 80.

[0050] As an example, in one embodiment, the housing 20 may be approximately 5 cm, the distance 83 between the fulcrum 248 and the collimating lens 36 may be approximately 3 cm, and the distance 84 between the fulcrum and the distal end 82 of adjustment tool 80 may be approximately 1 m. In such embodiment, the ratio of movement of the end 91 of the column of light 90 at the collimating lens 36 relative to the movement of the distal end 82 of adjustment tool 80 may be calculated as 3/100 or 3%. Accordingly, moving the end 91 of the column of light 90 by 10 μm requires movement of the distal end 82 of adjustment tool 80 by 333.33 μm or 0.33 mm. Accordingly, the use of a pivotable reflector module 40, 140, 240, 340 together with the adjustment tool 80 simplifies relatively fine movement of the column of light 90 in order to permit optimization of or maximizing the amount of light that is reflected by the gas analysis modules 10, 110, 210, 310.

[0051] Although each embodiment depicts the lens module being fixed relative to the housing and moving the reflector module relative to the housing and the lens module to adjust the path of the column of light, other configurations are contemplated. For example, the reflector module may be fixed relative to the housing and the lens module moved relative to the reflector module and the housing. In still another example, the lens module and the reflector module may be movable relative to each other, fixed relative to each other to create a subassembly and the subassembly subsequently fixed to the housing.

[0052] Gas analysis modules 10, 110, 210, 310 and feedback system 60 are depicted as being configured for measuring CO_2 as part of a capnography system. However, gas analysis modules 10, 110, 210, 310 may be used with feedback systems that are operative to transmit other wavelengths of light. In addition, the gas analysis modules 10, 110, 210, 310 may be used to analyze other gasses besides CO_2 passing within the gas analysis modules.

[0053] It will be appreciated that the foregoing description provides examples of the disclosed system and technique. However, it is contemplated that other implementations of the disclosure may differ in detail from the foregoing examples. All references to the disclosure or examples thereof are intended to reference the particular example being discussed at that point and are not intended to imply any limitation as to the scope of the disclosure more generally. All language of distinction and disparagement with respect to certain features is intended to indicate a lack of preference for those features, but not to exclude such from the scope of the disclosure entirely unless otherwise indicated.

[0054] Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

[0055] Accordingly, this disclosure includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the disclosure unless otherwise indicated herein or otherwise clearly contradicted by context.

CLAIMS:

1. A gas analysis module comprising:

a housing having a passage with a source section and a reflector section;

a reflector module disposed on the housing at the reflector section, the reflector module including a reflector;

a lens module disposed on the housing at the source section and spaced from the reflector module, the lens module including a waveguide and an aligned collimating lens defining a light path optically aligned with the reflector;

a mounting structure between the reflector module and the housing to permit movement of the reflector module relative to the lens module; and

a fixing element between the housing and the reflector module to secure the reflector module relative to the lens module.

2. The module of claim 1, wherein the mounting structure permits pivotal movement of the reflector module relative to the housing.

3. The module of claim 1, wherein the mounting structure includes a plurality of spaced apart engagement projections disposed around an inner surface of the passage between the housing and the reflector module.

4. The module of claim 3, wherein the engagement projections project inwardly from the inner surface towards the reflector module.

5. The module of claim 3, wherein the mounting structure includes at least 3 engagement projections.

6. The module of claim 1, wherein the mounting structure includes a deformable member between an inner surface of the passage and the reflector module.

7. The module of claim 1, wherein the mounting structure is a generally spherical surface formed on a portion of the reflector module.

8. The module of claim 1, wherein the fixing element is an adhesive.

9. The module of claim 8, wherein the adhesive is an instant hardening bonding agent.

10. The module of claim 8, wherein the adhesive is UV cured adhesive.

11. The module of claim 1, wherein the reflector module includes a tool engaging member configured to be engaged by a tool extending outside of the housing.

12. The module of claim 11, further including a cover secured to the housing and enclosing the tool engaging member within the housing.

13. The module of claim 11, wherein the housing includes an adjustment aperture through which a portion of the tool engaging member extends.

14. The module of claim 11, wherein the housing includes an adjustment aperture providing access to the tool engaging member and through which a portion of a tool for engaging the tool engaging member may pass.

15. The module of claim 1, wherein the waveguide is a single mode optical fiber and the lens module includes an aperture with a portion of the single mode optical fiber disposed therein.

16. The module of claim 1, wherein the waveguide and collimating lens are configured to permit infrared light to pass therethrough.

17. The module of claim 1, wherein the waveguide is a first waveguide and further including a second waveguide, the first and second waveguides being aligned with the collimating lens.

18. The module of claim 17, wherein the first and second waveguides are generally parallel.

19. A method of manufacturing a gas analysis module comprising:

providing a housing having a passage with a source section and a reflector section;

positioning a reflector module on the housing at the reflector section, the reflector module including a reflector;

positioning a lens module on the housing at the source section and spaced from the reflector module, the lens module including a waveguide and an aligned collimating lens;

providing a light source through the waveguide and the collimating lens to define a light path;

reflecting light from the light path off the reflector and through the collimating lens to a measuring system;

measuring an amount of reflected light received at the measuring unit;

pivoting the reflector module relative to the lens module to adjust an angular alignment position of the reflector relative to the light path;

repeating the steps of measuring and pivoting to adjust the angular alignment position of the reflector relative to the lens module through a plurality of angular alignment positions until an amount of reflected light meets a predetermined threshold; and

securing the reflector module relative to the lens module at an angular position corresponding to an angular position at which the amount of reflected light meets the predetermined threshold.

20. The method of claim 19, wherein the reflector module includes a tool engaging member and further including engaging the tool engaging member with a tool to pivot the reflector module relative to the lens module.

21. The method of claim 20, further including securing a cover to the housing to enclose the tool engaging member within the housing.

22. The method of claim 20, wherein the housing includes an adjustment aperture through which a portion of the tool engaging member extends, and the pivoting step includes moving the portion of the tool engaging member within the aperture.

23. The method of claim 20, wherein the housing includes an adjustment aperture providing access to the tool engaging member, and further including positioning a portion of a tool in the adjustment aperture and engaging the tool engaging member.

24. The method of claim 19, further including providing a mounting structure between the reflector module and the housing, and the pivoting step includes pivoting the reflector module about the mounting structure.

25. The method of claim 19, wherein the securing step includes applying an instant hardening bonding agent.

26. The method of claim 19, wherein the securing step includes applying an epoxy and curing the epoxy.

27. The method of claim 26, wherein the epoxy is a UV cured epoxy and the curing step includes applying UV light.

28. The method of claim 19, wherein the waveguide is a first waveguide and the lens module further includes a second waveguide, the first and second waveguides being aligned with the collimating lens, and further including transmitting the reflected light through the second waveguide and to the measuring unit.

29. A gas analysis module comprising:

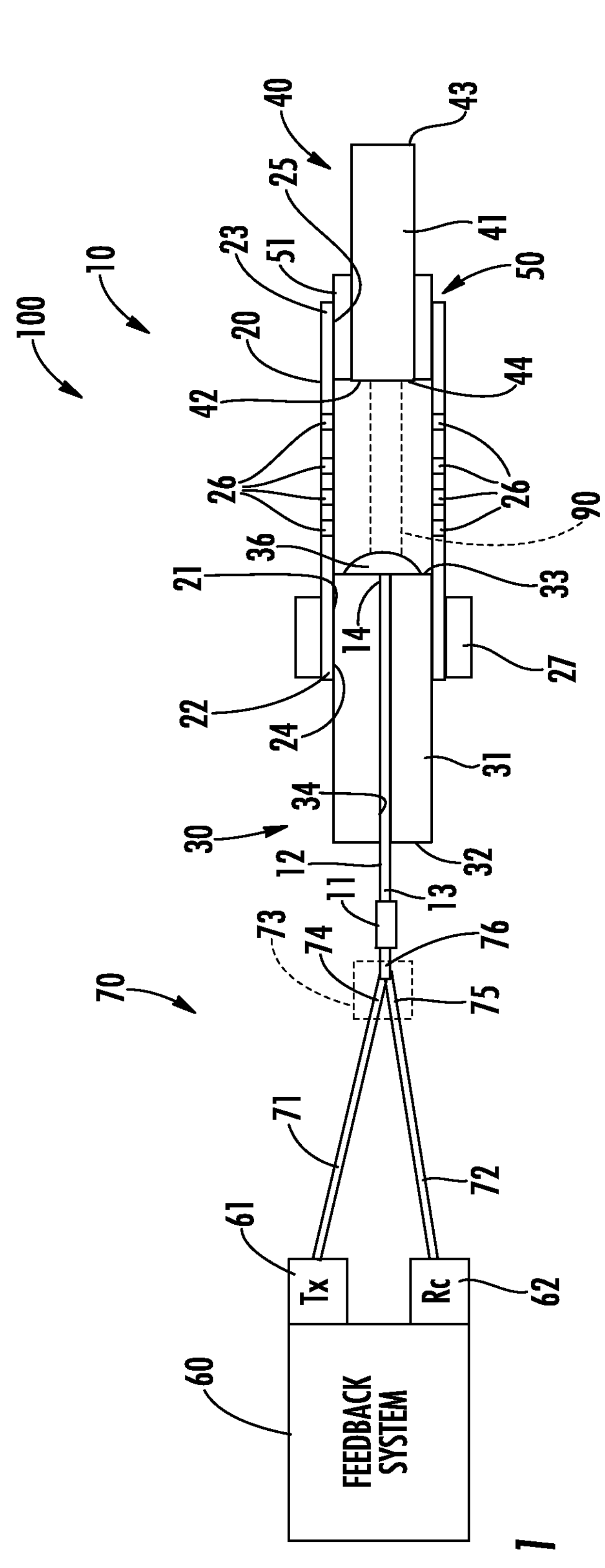
a housing having a passage with a source section and a reflector section;

a reflector module disposed on the housing at the reflector section, the reflector module including a reflector;

a lens module disposed on the housing at the source section and spaced from the reflector module, the lens module including a waveguide and an aligned collimating lens defining a light path optically aligned with the reflector;

a mounting structure permits relative movement of the reflector module and the lens module; and

a fixing element is operative to secure the reflector module relative to the lens module.



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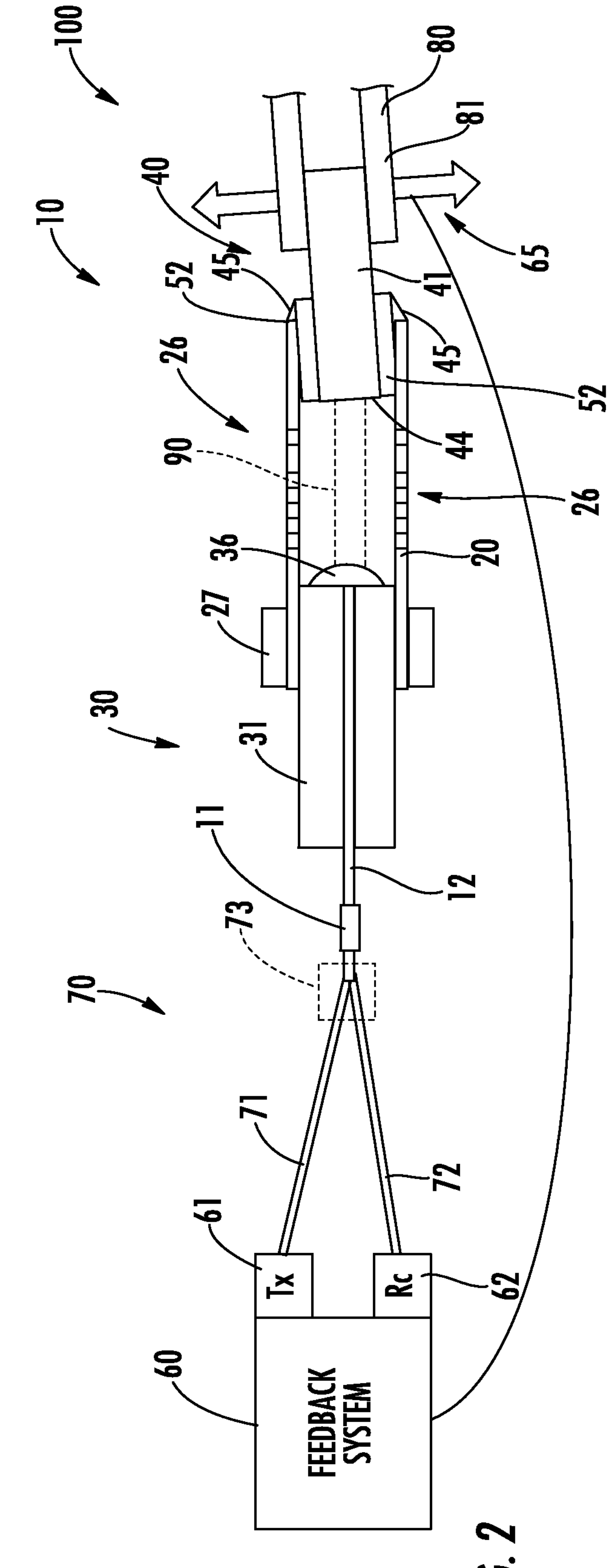


FIG. 2

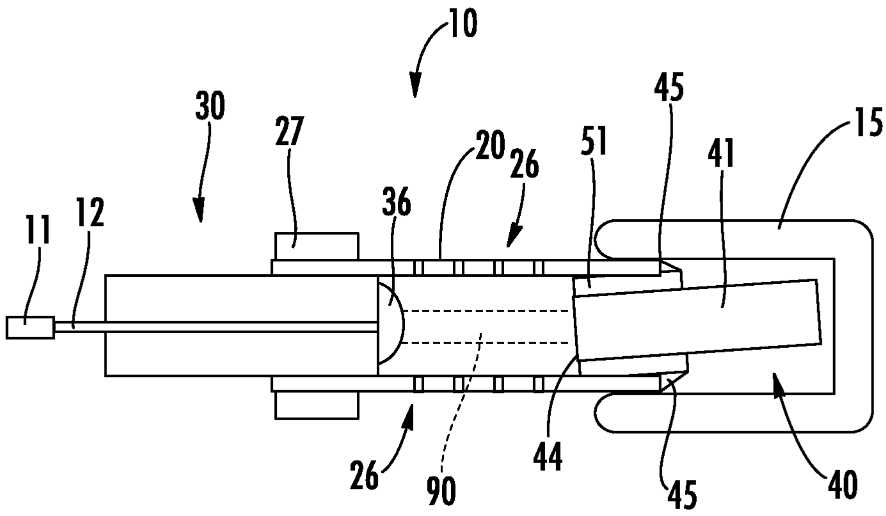
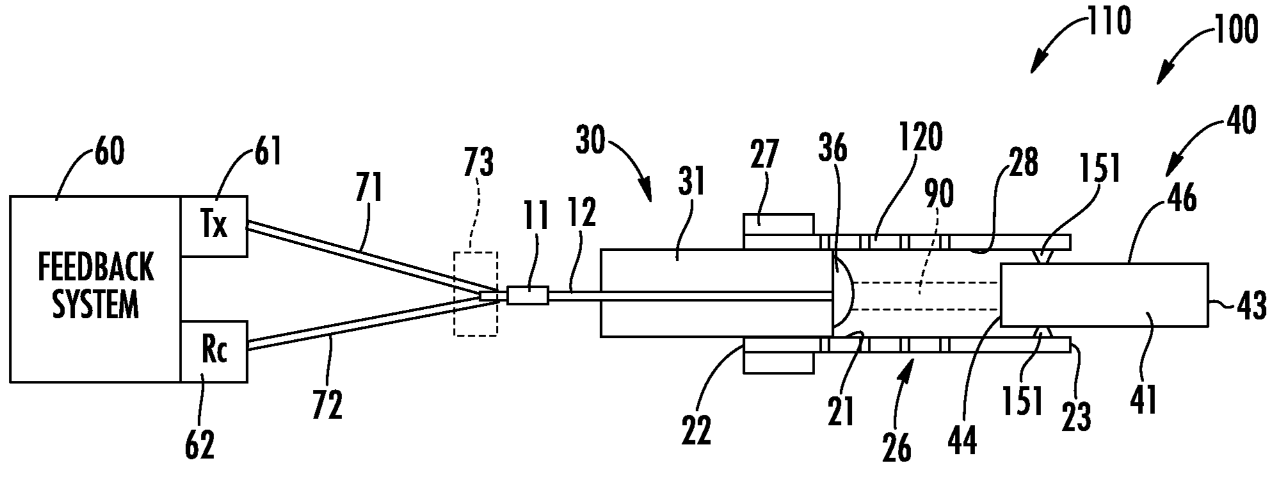


FIG. 3



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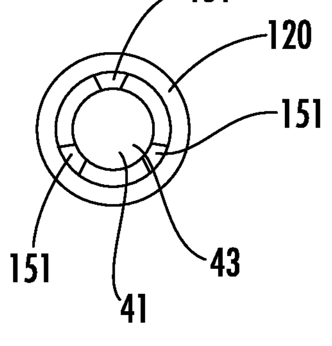
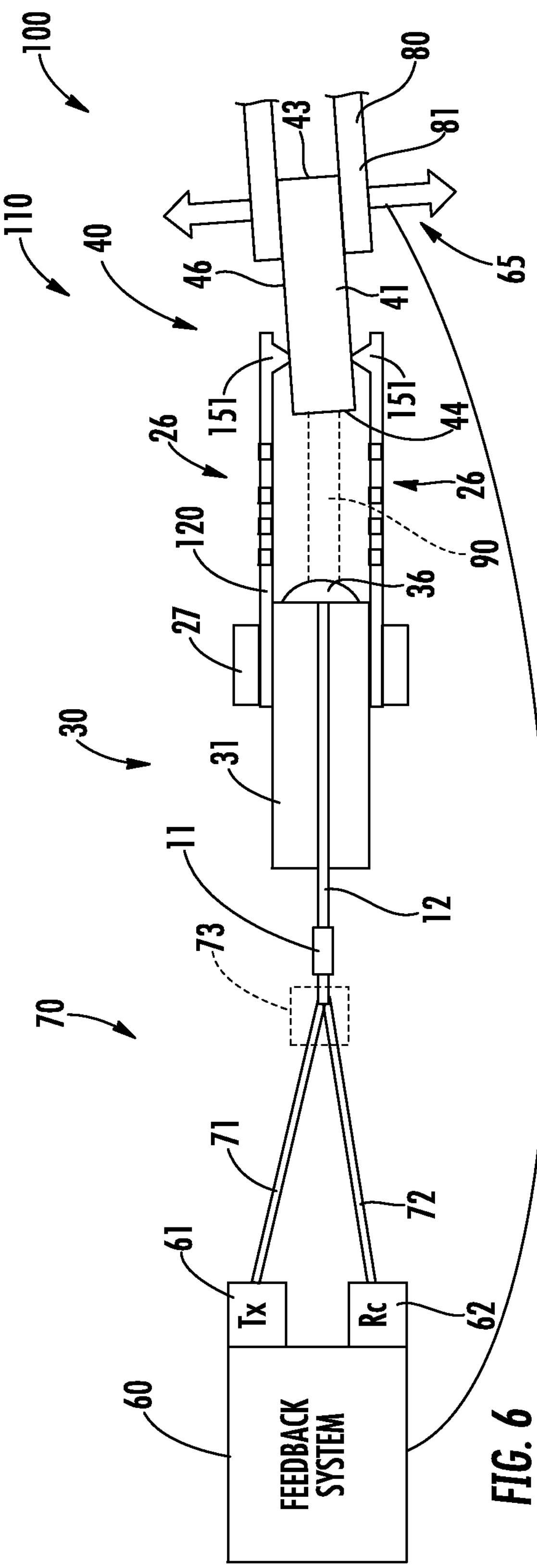


FIG. 5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FEEDBACK SYSTEM

FIG. 6

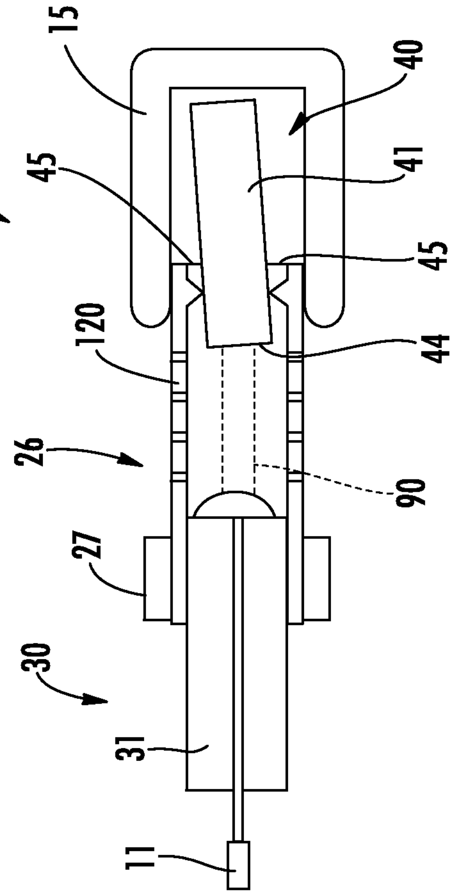
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FIG. 7

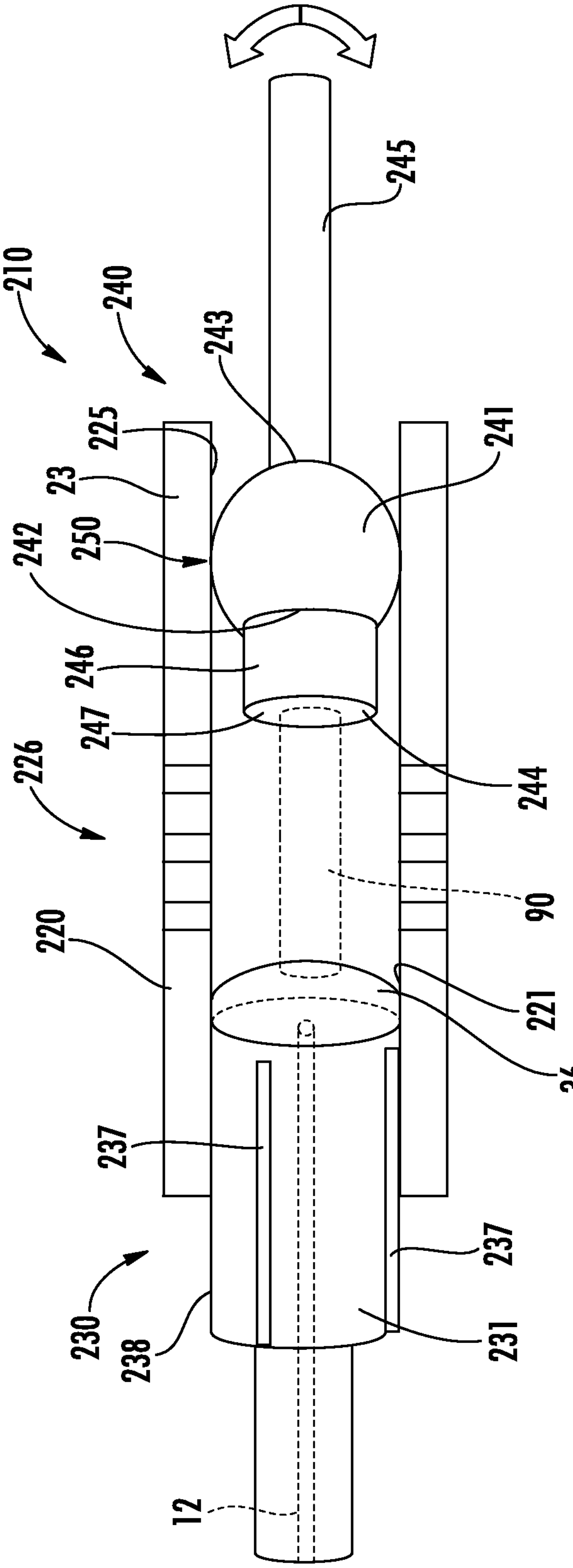
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FIG. 8

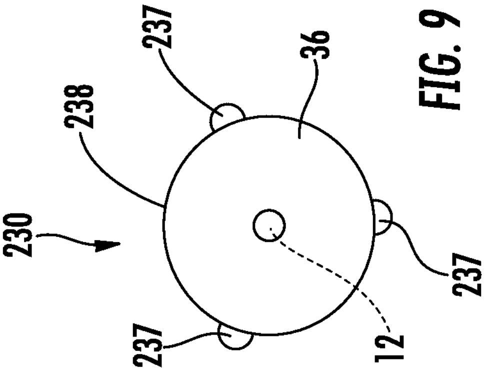
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FIG. 9

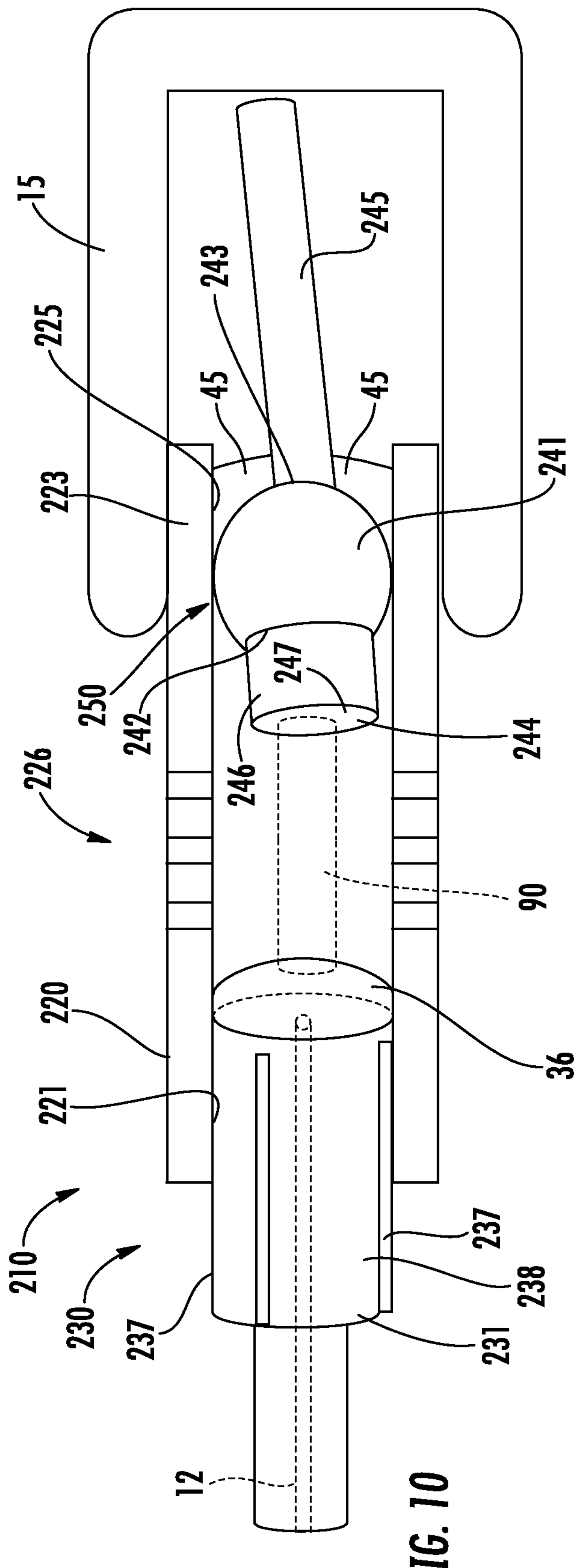

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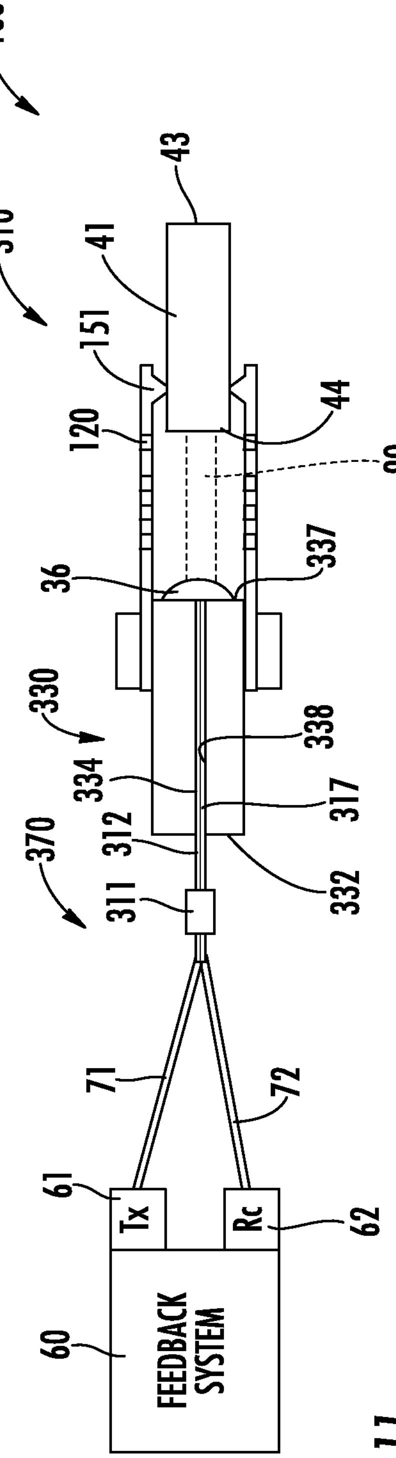
FIG. 10



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FEEDBACK SYSTEM

FIG. 11

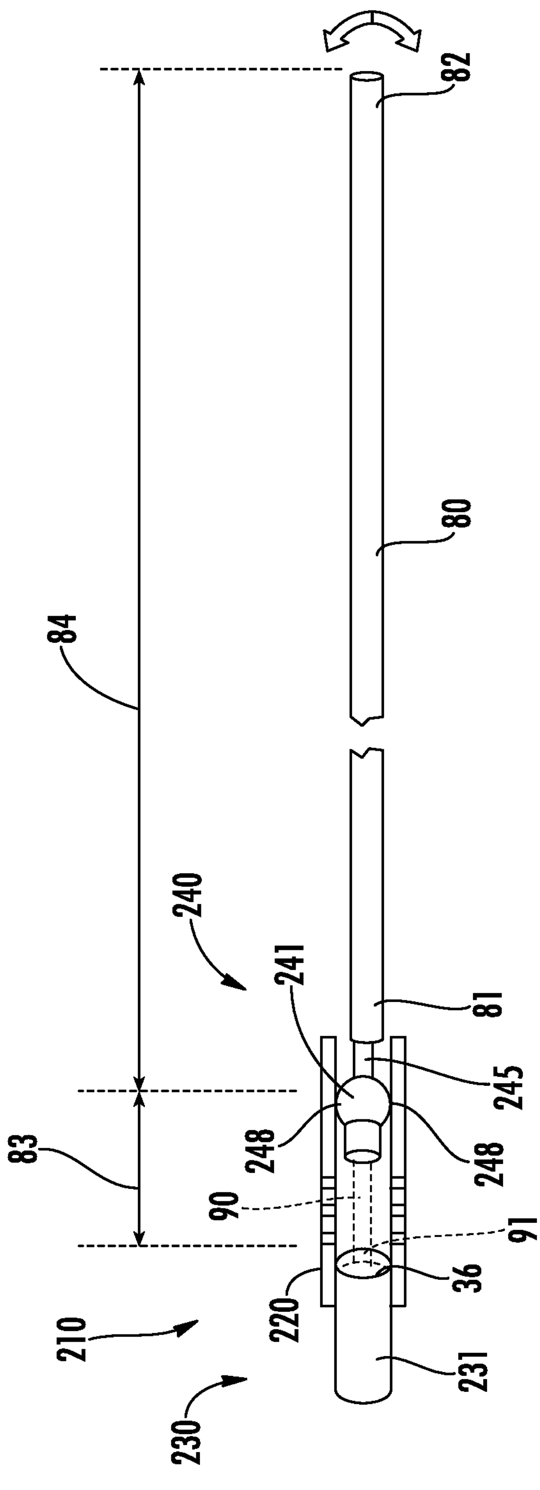

FIG. 12

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2016-0129-WO	**FOR FURTHER ACTION** see Form PCT/ISA/220 as well as, where applicable, item 5 below.	
International application No. **PCT/US2017/040174**	International filing date *(day/month/year)* **30 June 2017 (30.06.2017)**	(Earliest) Priority Date *(day/month/year)* 01 July 2016 (01.07.2016)
Applicant **MOLEX, LLC**		

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of **3** sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of :
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into __________, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. **1**
      ☐ as suggested by the applicant.
      ☒ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/040174

A. CLASSIFICATION OF SUBJECT MATTER

G01N 21/55(2006.01)i, G01N 21/3504(2014.01)i, G01N 33/497(2006.01)i, G01N 33/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01N 21/55; F23M 20/00; A61B 1/00; G01N 21/84; G01N 21/17; H01J 5/16; G01N 21/39; G01N 21/09; G01N 21/3504; G01N 33/497; G01N 33/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: gas, sensor, carbon dioxide, detect, collimating lens, optic, cable, fiber, mounting, reflector, cap, holder, pivot, movement and analysis

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5059790 A (KLAINER et al.) 22 October 1991 See column 12, lines 9-13, 52-59, column 14, lines 11-32, column 16, lines 61-65 and figures 1E, 3A-3B, 7A-8B, 15A-15B.	1-10,29
Y		11-28
Y	US 2012-0250006 A1 (KREMEYER, KEVIN) 04 October 2012 See abstract, paragraph [0064] and figure 8.	11-14,20-23
Y	US 2015-0109618 A1 (HOWELL et al.) 23 April 2015 See paragraphs [0056]-[0067] and figure 5.	15-28
A	JP 2015-091339 A (GENERAL HOSPITAL CORP.) 14 May 2015 See abstract, paragraphs [0014]-[0016] and figures 2-3.	1-29
A	US 2015-0316466 A1 (PANASONIC CORPORATION) 05 November 2015 See paragraphs [0023]-[0025] and figure 1A.	1-29

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 September 2017 (22.09.2017)	**22 September 2017 (22.09.2017)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
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Authorized officer
LEE, Hun Gil
Telephone No. +82-42-481-8525

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